



# SK5223 FlexMatrix™ Keyboard Controller

Ultra-Low Power, User-Programmable SMBus I2C Keyboard Scanner with 8x20 Scan, PWM Backlight, Upgradable Bootloader

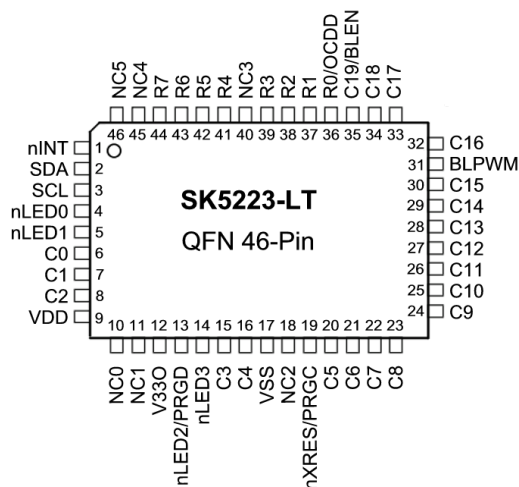
## FEATURES

- SMBus v1.1 (or I2C) interface with get UDID
- PEC CRC enabled communication
- Failure-safe Bootloader for firmware upgrade
- 8 x 20 matrix keyboard scan
- 1 PWM backlight brightness control
- 4 Keyboard LEDs
- Advanced ghost key detection algorithm to maximize the key combination without additional diodes
- Built-in oscillator and digital circuit. No external crystal is needed
- QFN 46 pin package: 6.5x4.5mm 0.9 Max (LxWxH) or
- LQFP 48 pin package: 7x7mm 1.6 Max (LxWxH)
- Low power consumption: @ 3V: 0.1uA (no key pressed) 110uA (1 key) 50uA (inc per Key)
- Operation voltage range: 2.2 to 5.5V
- Industrial temperature range: -40°C to +85°C
- Custom versions available in small and large quantities

## APPLICATION

- Notebook/Netbook PCs
- Tablet PCs
- Tablet/Mobile Phone docking station
- Instruments
- I/O Expander
- Wireless keyboards

## PIN ASSIGNMENTS



## DESCRIPTION

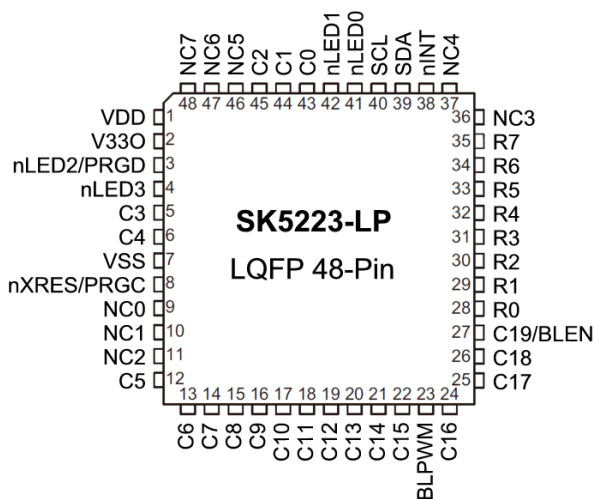
The SK5223 is an ultra-low power (0.1uA@3V) SMBus v1.1 (or I2C) interface keyboard encoder ASIC with 1 PWM backlight and 4 LEDs control. The failure-safe bootloader design allows the SK5223 to still have full keyboard functions even when any interruption failure happens during the firmware update. It's the best choice for customized keyboard design for battery powered notebook / netbook / tablet / docking station / Instrument / IO expander. The SK5223 deploys Sprintek FlexMatrix™ technology for users to upgrade firmware in the field.

The SK5223 scans and encodes an 8-row by 20-column matrix. The key press events are translated to keyboard event report.

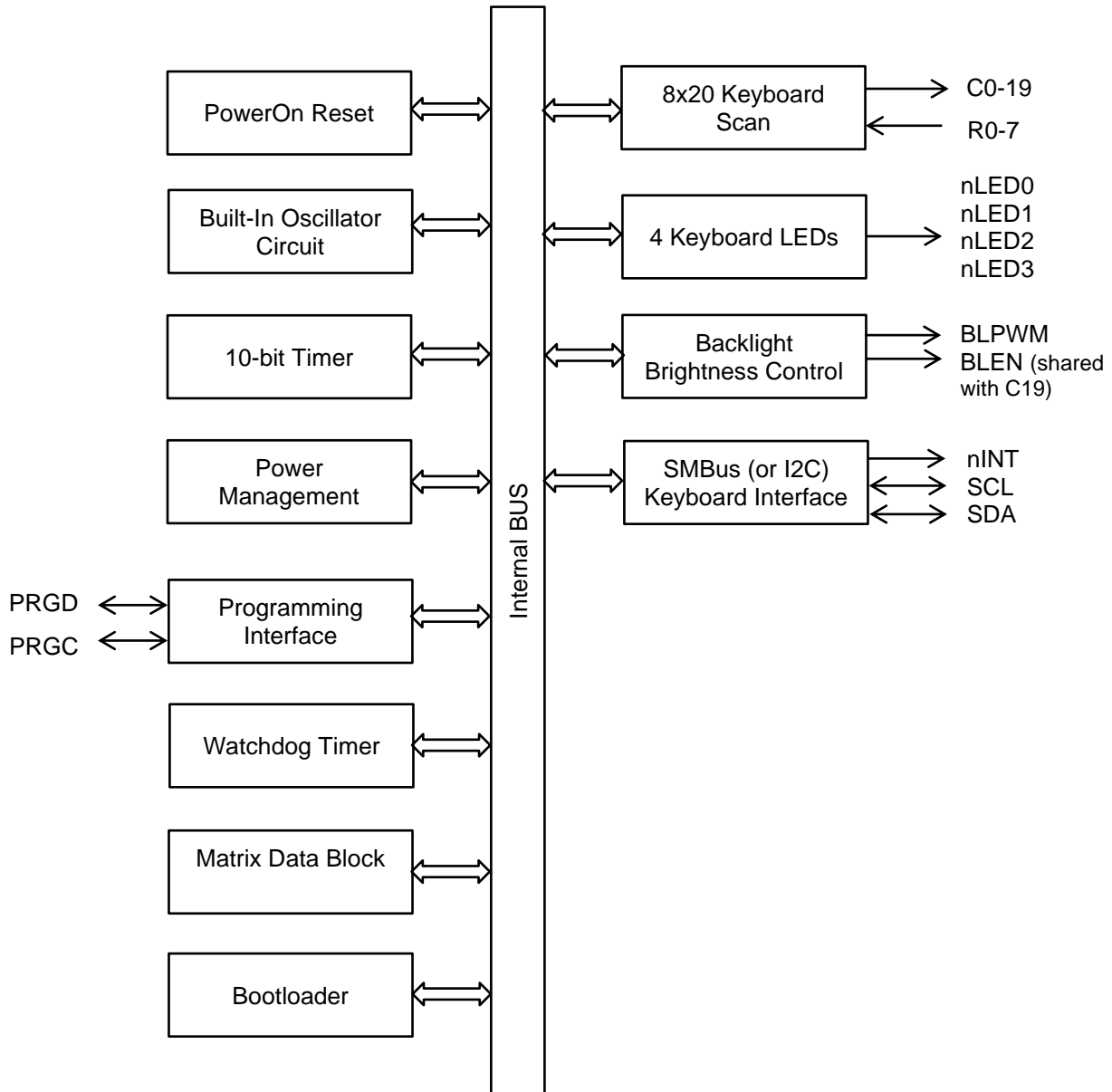
The SK5223 provides command-controlled PWM for backlight LED PWM brightness control. An IO pin BLEN can be used to turn off the backlight circuit totally. When BLEN is used, the keyboard scan will be 8-row by 19-columns.

## ORDEING INFORMATION

**SK5223-LT** QFN 46-pin, 0.4mm pitch, (6.5x4.5mm 0.9 MAX), Pb-Free, RoHS Complaint  
**SK5223-LP** LQFP 48-pin, 0.5mm pitch, (7x7mm 1.6 MAX), Pb-Free, RoHS Complaint



### FUNCTION BLOCK DIAGRAM



## PIN DEFINITION

### SK5223-LT Pin Definition

Pin No	Type	Name	Description
1	O	nINT	I2C slave interrupt line
2	IO	SDA	I2C slave data line
3	IO	SCL	I2C slave clock line
4	O	nLED0	LED0 drive line
5	O	nLED1	LED1 drive line
6 – 8	IO	C0 – C2	Column lines 0 to 2 for scan matrix
9	P	VDD	Power supply
10	NA	NC0	NC pin
11	NA	NC1	NC pin
12	P	V33O	Reserved
13	IO	nLED2/PRGD	LED2 drive line / programming data line
14	O	nLED3	LED3 drive line
15 – 16	IO	C3 – C4	Column lines 3, 4 for scan matrix
17	P	VSS	Ground connection
18	NA	NC2	NC pin
19	I	nXRES / PRGC	External reset: low active / programming clock line
20 – 30	IO	C5 – C15	Column lines 5 to 15 for scan matrix
31	O	BLPWM	Backlight control PWM
32 – 34	IO	C16 – C18	Column lines 16 to 18 for scan matrix
35	IO	C19 / BLEN	Column line 19 for scan matrix / Backlight control LDO enable
36 – 39	I	R0 – R3	Row lines 0 to 3 for scan matrix with internal pull-up resistor
40	NA	NC3	NC pin
41 – 44	I	R4 – R7	Row lines 4 to 7 for scan matrix with internal pull-up resistor
45 – 46	NA	NC4 - NC5	NC pins

LEGEND I = Input, O = Output, IO = Input/Output, P = Power, NA = Not used

### SK5223-LP Pin Definition

Pin No	Type	Name	Description
1	P	VDD	Power supply
2	P	V33O	USB 3.3 regulator output
3	IO	nLED2/PRGD	LED2 drive line / programming data line
4	O	nLED3	LED3 drive line
5 – 6	IO	C3 – C4	Column lines 3 to 4 for scan matrix
7	P	VSS	Ground connection
8	I	nXRES/PRGC	External reset: low active / programming clock line
9-11	NA	NC0-NC2	NC pins
12 – 22	IO	C5 – C15	Column lines 5 to 15 for scan matrix
23	O	BLPWM	Backlight control PWM
24 – 26	IO	C16 – C18	Column lines 16 to 18 for scan matrix
27	IO	C19 / BLEN	Column line 19 for scan matrix / Backlight control LDO enable
28 – 35	I	R0 – R7	Row lines 0 to 7 for scan matrix with internal pull-up resistor
36 – 37	NA	NC3-NC4	NC pins
38	O	nINT	I2C slave interrupt line
39	IO	SDA	I2C slave data line
40	IO	SCL	I2C slave clock line
41	O	nLED0	LED0 drive line
42	O	nLED1	LED1 drive line
43 – 45	IO	C0 – C2	Column lines 0 to 2 for scan matrix
46 – 48	NA	NC5-NC7	NC pins

LEGEND I = Input, O = Output, IO = Input/Output, P = Power, NA = Not used

## FUNCTION BLOCK DESCRIPTION

The SK5223 consists functionally of several major sections (see the block diagram on the previous page). These include power on reset, oscillator circuit, 10-bit timer, power management, programming interface, watchdog timer, keyboard scan, keyboard LEDs, backlight brightness control, matrix data block, bootloader, SMBus I2C keyboard interface. All sections communicate with each other and operate concurrently.

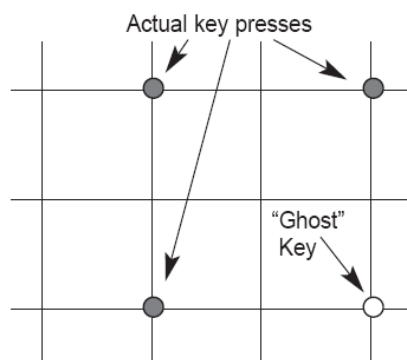
### Keyboard Scan

The SK5223 scans a keyboard organized as an 8 row by 20 column matrix for a maximum of 160 keys. Smaller size matrixes can be accommodated by leaving unused pins open. The IC provides internal pull-ups for the row input pins. When active, the encoder selects each row lines (R0-R7); for each row selected, it reads the column lines (C0-C19). A key closure is detected as a zero in the corresponding position of the matrix.

Each key found pressed is de-bounced for a period of 24ms. Once the key is verified, the corresponding key code(s) are loaded into the transmit buffer.

In any scanned contact switch matrix, whenever three keys defining a rectangle on the switch matrix are pressed at the same time, a fourth key positioned on the fourth corner of the rectangle is sensed as being pressed. This is known as the “ghost” or “phantom” key problem.

Although the problem cannot be totally eliminated without using external hardware, there are methods to neutralize its negative effects for most practical applications. Keys that are intended to be used in combinations should be placed in the same row or column of the matrix, whenever possible. Shift keys (Shift, Alt, Ctrl, Window, Fn) should not reside in the same row (or column) as any other keys. The SK5223 has built-in mechanisms to detect and reject “ghost” keys.



C19 and BLEN are shared. BLEN (backlight LDO enable) is selected at default. Therefore, the key matrix scan is 8x19 at default.

### Keyboard LEDs

The SK5223 provides 4 pins to directly drive general LED indicators which can be controlled via commands.

### SMBus I2C Interface

The SK5223 follows SMBus v1.1 spec with fixed slave address and PEC. It implements proprietary SMBus protocols to report keyboard events and a command (0x03) to pull UDID. See details in document “Sprintek SMBus Keyboard Controller Communication Protocol”.

nINT pin is low assertion to indicate that the SK5223 has events to report.

### Power Management

The SK5223 automatically enters low power modes at operation conditions. Under 3V operation, when no key is pressed, the SK5223 enters low power mode and only consumes 0.1uA; when one key is pressed, the SK5223 consumes only 110uA; when two or more keys are pressed, the SK5223 consumes only 50uA per extra key. The ultra-low power consumption makes it well fit battery-powered devices.

## Backlight Brightness Control

The 10-bit PWM output controls the brightness of backlight circuit. The PWM clock is sourced from 6MHz clock, and the parameters such as frequency, pulse width, auto-off time are programmable.

An extra signal BLEN is automatically driven low to turn off the whole circuitry when PWM duty is 0% to minimize power consumption; while BLEN is automatically driven high when PWM duty is not 0%.

## Power On Reset Circuit

The SK5223 has built-in power on reset circuit with simple external RC components.

## Oscillator Circuit

The SK5223 has built-in oscillator circuit and no external crystal or resonator is needed.

## 10-bit Timer

The 10-bit timer provides the timing control for I2C communication, keyboard scan and sleep timer wakeup.

## Programming Interface

The programming interface is reserved for Sprintek to programming new firmware. **PRGC and PRGD pins are recommended to be connected to a 6 pin header in the schematic.** The header needn't be populated in the final assembly. Three test points are preferred if 6 pin header is not allowed due to space reason.

## Watchdog Timer

The SK5223 utilizes a 500ms watchdog timer to ensure robust firmware design.

## Matrix Data Block

The SK5223 provides an on-chip data block to store configuration data. The data block can be changed in the field. Custom matrix data block can be done via Sprintek custom software or customization service.

## BootLoader

The SK5223 deploys a bootloader to update the newer version firmware via SMBus bus. The failure-safe design allows the SK5223 still have full keyboard functions even when any interruption failure happens during the firmware update.

## SMBus COMMAND PROTOCOL

### SMBus Slave Device Address

The 7-bit address of the device is shown as below 0x39. After combined with R/W bit, the 8-bit address is 0x72 for I2C write operation, 0x73 for I2C read operation.

### SMBus Based Low Level Communication

The Controller follows SMBus protocol with PEC always enabled.

**Table – Host to SMBus keyboard controller I2C Packet Formats**

SMBus Protocol	
Write Byte	S   Address   W   {A}   Command   {A}   Data Byte   {A}   PEC   {A}   P
Read Byte	S   Address   W   {A}   Command   {A}   S   Address   R   {A}   {Data Byte}   A   {PEC}   nA   P
Write Word	S   Address   W   {A}   Command   {A}   Data Low   {A}   Data High   {A}   PEC   {A}   P
Read Word	S   Address   W   {A}   Command   {A}   S   Address   R   {A}   {Data Low}   A   {Data High}   A   {PEC}   nA   P
Block Read	S   Address   W   {A}   Command   {A}   S   Address   R   {A}   {Byte Count}   A   {Byte 0}   A   {Byte 1}   A   ...   {Byte N}   A   {PEC}   nA   P
Block Write	S   Address   W   {A}   Command   {A}   Byte Count   {A}   Byte 0   {A}   Byte 1   {A}   ...   Byte N   {A}   PEC   {A}   P

**Legend:** S = Start, P = Stop, A = Ack, nA = NAck, W=Write (0), R=Read (1)

Items in { } are sent from the slave (Keyboard controller) to the master (Host controller)

## Events

### Event Format

The device can notify the host when certain events happen. The device will assert nINT line first; then wait for the host send “Read Events” command to query what events happens. Each event is led by an event identification byte, then followed by zero or more data bytes.

Event Table

Event Name	Event Code	Description
EVENT_KEYSTROKE	0x00	Keyboard event. Followed by one-byte keyboard status. See keyboard event table.
EVENT_KEYSTROKE1	0x17	Keyboard event. Followed by one-byte keyboard status. See keyboard event table.
EVENT_RESET_COMPLETE	0x04	Sent when POR
EVENT_FWU_STATUS	0x06	Event generated by SMBus bootloader. See further in FWU status table.
EVENT_BACKLIT_OFF	0x07	When backlit is turned off when backlit timeouts.
EVENT_PROD_INFO_STATUS	0x08	Not supported
EVENT_CHECKSUM	0x15	Followed by 3-byte data. Byte0: verification status Byte1: Checksum low byte Byte2: Checksum high byte Byte3: Area
EVENT_BUFFER_EMPTY	0xFF	When no event is in the even buffer, it's sent.

### Keyboard Event Format (Event ID 0x00 and Event ID 0x17)

Keyboard events are represented in single byte that indicates the row and column of the key that changed state.

Event ID 0x00		Keyboard Event Format
Bits	Description	
7	<b>Key Press/Release</b> 1=Key was pressed, 0=Key was released	
4:6	<b>Keyboard Matrix Row</b> Key scan input number (0-7)	
3:0	<b>Keyboard Matrix Column</b> Key scan output number (0-15 depending on number of columns used)	

Event ID 0x17		Keyboard Event Format
Bits	Description	
7	<b>Key Press/Release</b> 1=Key was pressed, 0=Key was released	
4:6	<b>Keyboard Matrix Row</b> Key scan input number (0-7)	
3:0	<b>Keyboard Matrix Column</b> Key scan output number (16-31 depending on number of columns used)	

### List of Commands Of Application Code

Command 0x03 – Get UDID  
 Command 0x82 – Read Events  
 Command 0xC0 – Reset Device  
 Command 0xC1 – Get Device Information  
 Command 0xC2 – Calculate Checksum  
 Command 0x90 – FWU Init  
 Command 0x83 – Set LEDs  
 Command 0x8C – Reset Backlit Timer  
 Command 0x94 – Set Backlit Timeout  
 Command 0x95 – Toggle Backlit AutoOn  
 Command 0xC5 – Set Backlit Period and Duty

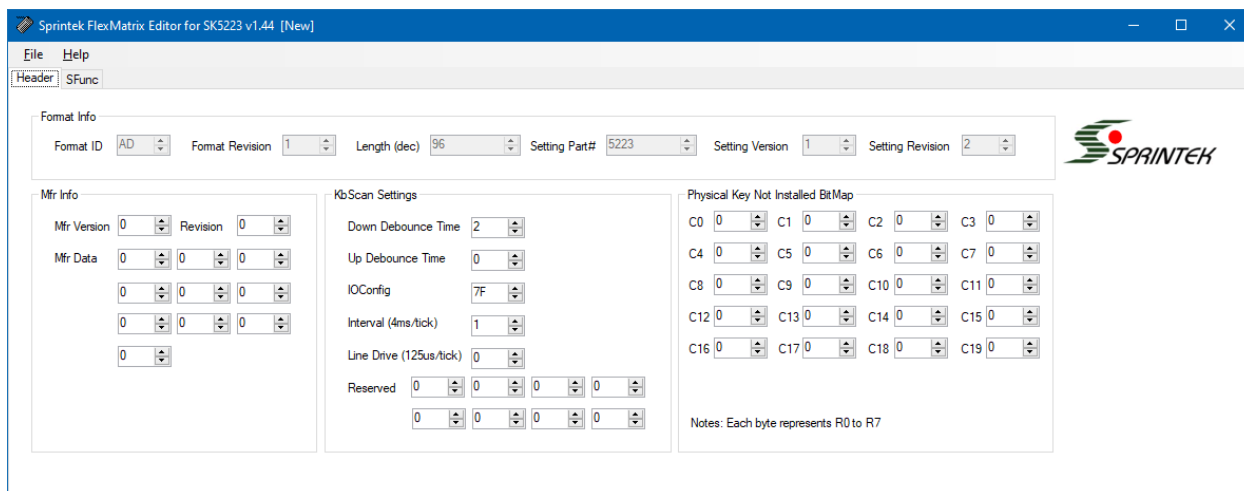
## KEYBOARD MATRIX DESIGN

### Design Keyboard Matrix

The SK5223 reports keyboard location (row, column) to the host, so no matrix scan code mapping table is needed. The tables shall be defined at the host controller. The scan code table can be seen in the following section “*HID Usage Tables 1.2*” from [www.usb.org](http://www.usb.org). Please refer to Microsoft Windows Platform Design Notes “Keyboard Scan Code Specification” to get more information.

Keyboard scan and backlight control settings can be configured via FlexMatrix Editor software.

The Editor program can be downloaded from <http://sprintek.com/support/Downloads.aspx>. Here is the screen snapshot of FlexMatrix Editor software.



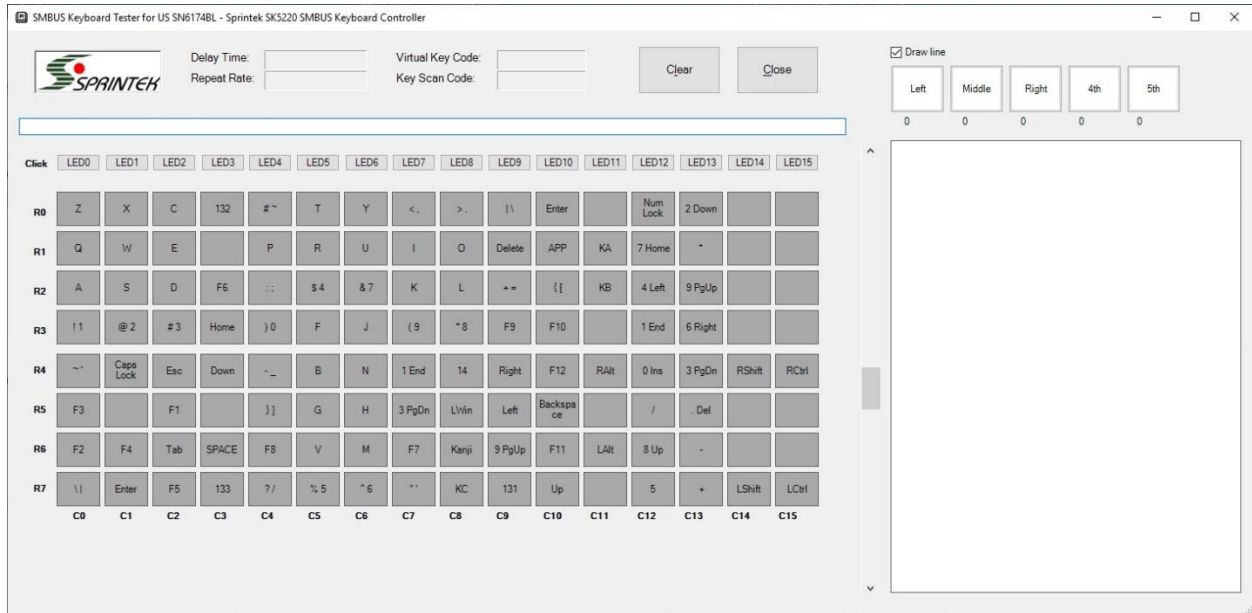
Screen snapshot of FlexMatrix™ Editor

### Test Keyboard Matrix

Sprintek offers a keyboard test tool to verify your keyboard design. The FlexMatrix Tester software can be downloaded from the download page on the Sprintek web site <http://sprintek.com/support/Downloads.aspx>

Here is the screen snapshot of FlexMatrix Tester software.



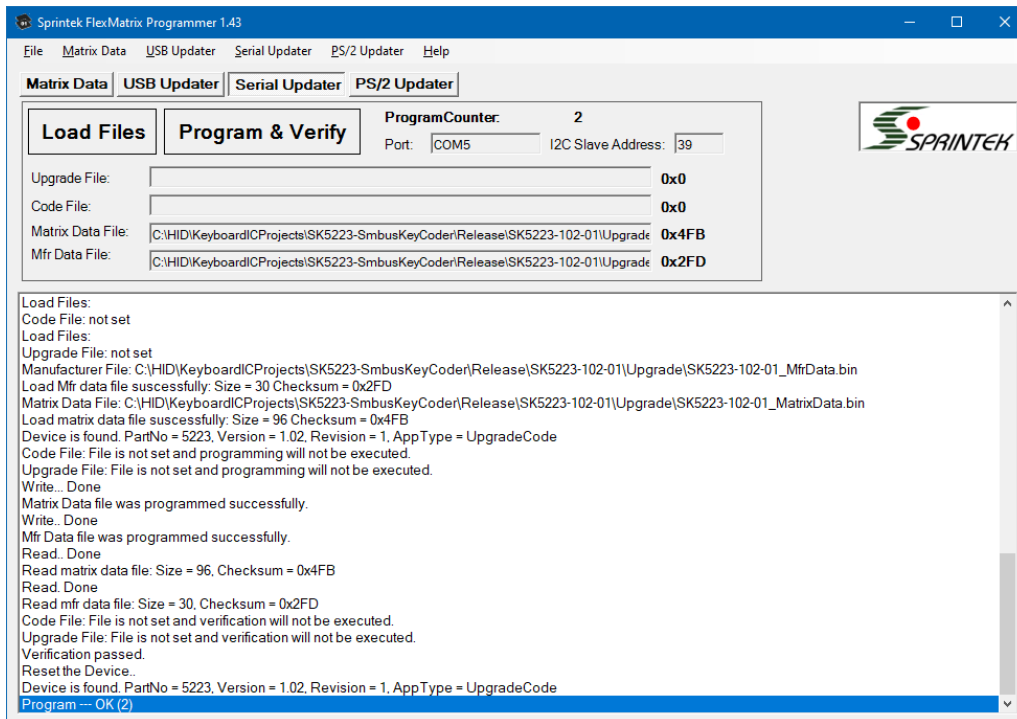


Screen snapshot of FlexMatrix™ SerialTerminal

## Download Keyboard Matrix

The FlexMatrix Programmer program enables the user to download matrix binary file to the SK5223, upload matrix data from the SK5223's flash data block to a binary file.

The Programmer program can be downloaded from <http://sprintek.com/support/Downloads.aspx>. Here is the screen snapshot of FlexMatrix Programmer software.

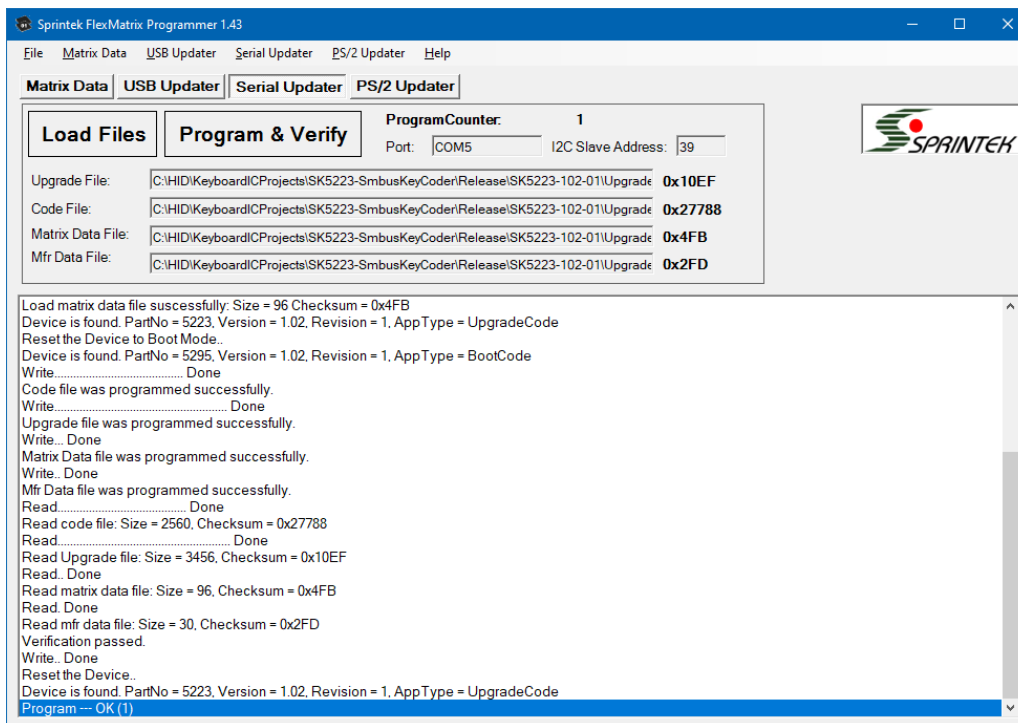


Screen snapshot of FlexMatrix™ Programmer – Matrix Data Upgrade

## Code Upgrade

The SK5223's bootloader to support field code upgrade. The feature enables users to enjoy new features of your design. 3 files can be upgraded via the FlexMatrix Programmer program: code file, matrix data, manufacturer data.

The Tester program can be downloaded from <http://sprintek.com/support/Downloads.aspx>. Here is the screen snapshot of FlexMatrix Programmer software.



Screen snapshot of FlexMatrix™ Programmer – Code Upgrade

## DEFAULT KEYBOARD MATRIX

The SK5223 reports keyboard location (row, column) to the host, so no matrix scan code mapping table is needed. The tables shall be defined at the host controller. The scan code table can be seen in the following section “*HID Usage Tables 1.2*” from [www.usb.org](http://www.usb.org).





## ELECTRONICS SPECIFICATION

### Absolute Maximum Ratings

Symbol	Description	Min	Typ	Max	Units	Notes
TSTG	Storage Temperature	-50	25	+125	°C	
VDD	Supply Voltage on Relative to VSS	-0.3	-	+6.0	V	
VIO	DC Input Voltage	VSS-0.3	-	VDD+0.3	V	
IMTO	Maximum Current into all pins in total	-100	-	+150	mA	

### Operating Temperature

Symbol	Description	Min	Typ	Max	Units	Notes
TOP	Operating Temperature	-40	-	+85	°C	

### DC Electrical Characteristics

Symbol	Description	Min	Typ	Max	Units	Notes
VDD	Supply Voltage at USB regulator enabled interface	2.2	-	5.5	V	
IDD	Supply Current when no key is pressed		0.3	2	uA	5V
			0.1	1	uA	3V
IDDK	Supply Current when one key is pressed		260		uA	5V
			110		uA	3V
IDDE	Incremental Supply Current when one more key is pressed		115		uA	5V
			50		uA	3V
LVR	Low voltage reset	1.995	2.1	2.205	V	
RPU	Pull-up Resistor	10	30	50	kΩ	5V
		20	60	100	kΩ	3V

### GPIO Electrical Characteristics

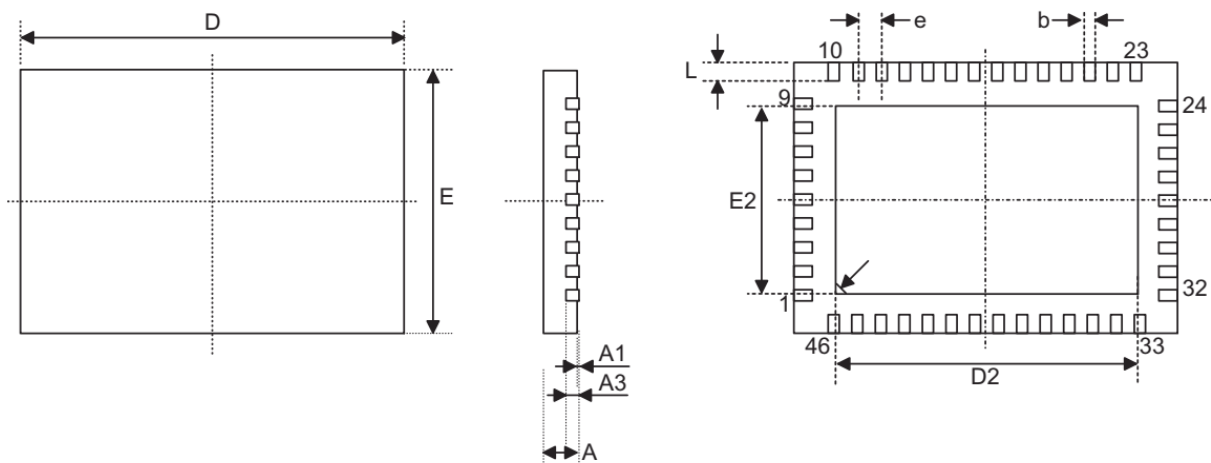
Symbol	Description	Min	Typ	Max	Units	Notes
VIL	Input Low Level	-	-	0.2VDD	V	
VIH	Input High Level	0.8VDD	-	-	V	
BLFPWM	Backlight PWM frequency	91.5	366	46,875	Hz	366Hz is default.

### I2C Slave Electrical Characteristics

Symbol	Description	Min	Typ	Max	Units	Notes
BI2C	I2C baud rate	-	-	400k	Hz	

## PACKAGING INFORMATION

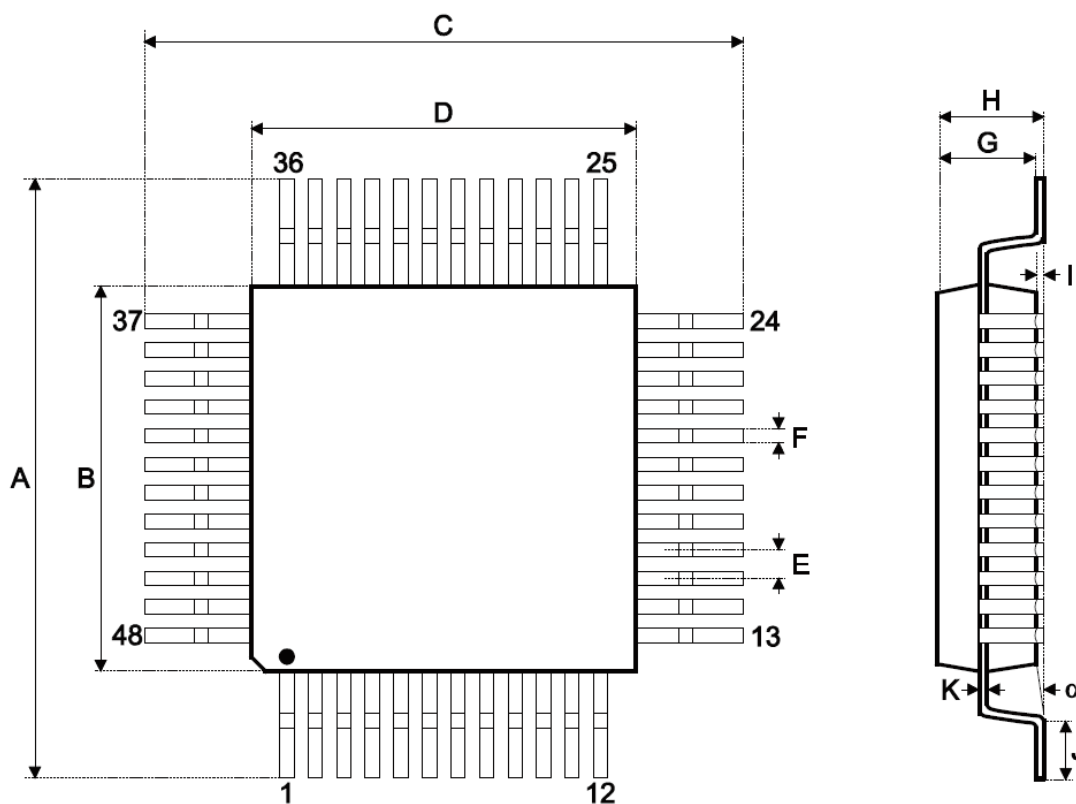
### SK5223-LT Drawing



Symbol	Dimensions in mm		
	Min.	Nom.	Max.
A	0.8	0.85	0.9
A1	0	0.02	0.04
A3	-	0.2 ref	-
b	0.15	0.2	0.25
D	6.45	6.5	6.55
E	4.45	4.5	4.55
e	-	0.4 BSC.	-
D2	5	5.1	5.2
E2	3	3.1	3.2
L	0.3	0.4	0.5

### SK5223-LT 46-pin (6.5x4.5mm 0.9 MAX) SAW Type QFN

## SK5223-LP Drawing



Symbol	Dimensions in mm		
	Min.	Nom.	Max.
A	-	9.00BSC	-
B	-	7.00BSC	-
C	-	9.00BSC	-
D	-	7.00BSC	-
E	-	0.50BSC	-
F	0.17	0.22	0.27
G	1.35	1.40	1.45
H	-	-	1.60
I	0.05	-	0.15
J	0.45	0.60	0.75
K	0.09	-	0.20
$\alpha$	0°	-	7°

SK5223-LP 48-pin (7x7mm 1.6 MAX) LQFP

## **SALE AND SERVICE INFORMATION**

To obtain information about Sprintek Corporation or FlexMatrix keyboard controller family sales and technical support, reference the following information.

### **Sprintek Corporation**

4969 Corral St.

Simi Valley, CA 93063, USA

Web Site: <http://www.sprintek.com>

## **REVISION HISTORY**

<b>Revision</b>	<b>Issue Date</b>	<b>Description</b>
1.00	August 12, 2020	Initial release